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Designing and Implementing a New Supply Chain Paradigm for Airplane Development

by

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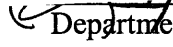
Submitted to the Department of Civil and Environmental Engineering and the Sloan
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Master of Science in Civil and Environmental Engineering
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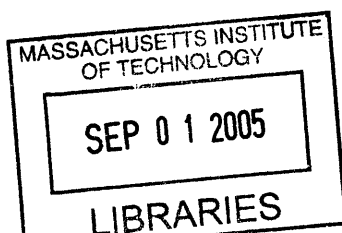
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BARKER

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Abstract

The 787 program is the latest airplane development program in Boeing Commercial Airplanes. In this program, many new business processes, including a new supply chain structure will be implemented.

Based on my six-month internship in Boeing, this thesis will address two critical supply chain issues that the 787 program currently faces and offer recommendations. The two issues are as follows:

- Boeing currently plays a very active role in managing the ordering and scheduling protocols for drop-shipped components. Drop-shipped components are parts that are ordered by Boeing but to be delivered to another supplier or subcontractors for installation and assembly. Current processes will not be adequate to handle the large amount of drop-shipped components in the 787 program. It is recommended that Boeing sets up a supplier portal to manage the interactions with and between partners.
- Current non-compliance management processes for drop-shipped components are not efficient enough for the 787 program. To solve this problem, it is recommended that Boeing devotes dedicated resources to work with individual structural partners on their sites to facilitate managing the non-conformance processes.

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Thesis Overview

This thesis is written based on my six-month internship at the Boeing Company in Everett, Washington, from June to December 2004. My internship project is sponsored by the vice president of manufacturing and quality in the 787 program, Mr. Scott Strode and supervised by Professor Jérémie Gallien from the Operations Management group in MIT Sloan School of Management, and by Professor David Simchi-Levi from the Department of Civil and Environmental Engineering in the School of Engineering at MIT.

This thesis is organized as follows. Section I sets the stage by providing an overview of the major players, industry dynamics and recent developments in the commercial aircraft manufacturing industry. Section II dives deep into an analysis of the current supply chain architecture of the Boeing Company and the latest industry dynamics. In Section III, a detailed case study involving the unique supply chain challenges faced by the 787 program is presented, including the specific supply chain and operations issues that I investigated and addressed during my stay at Boeing.

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I. Industry Analysis

The commercial aerospace industry generates 28 million jobs worldwide and USD 1.4 trillion in annual gross output.¹ It is the biggest contributor to the US manufacturing trade balance, amounting to USD 26 billion dollars in net exports in 2002.² Today, the industry can be best characterized by a duopoly between the Boeing Company and Airbus Industries. Historically, Boeing has dominated the industry since the beginning of the jet age, thanks to a series of very successful models. It was not until the 1990s when the industry underwent a transformation from primarily a monopoly by Boeing, to a competitive duopoly. In 2004, Airbus attained the no.1 market position and delivered 35 more aircrafts than Boeing, accounting for 53% of total deliveries that year.

A. Major Players in the Industry

- **The Boeing Company**

The Boeing Company is the largest aviation, aerospace and defense company in the world. Based in Chicago, Illinois, Boeing is consisted of two main businesses; its defense division, Integrated Defense Systems (IDS, headquartered in St. Louis, Missouri), and its commercial division, Boeing Commercial Airplanes (BCA, headquarters in Seattle, Washington), the latter of which will be the main focus of this thesis. Key manufacturing sites for commercial airplanes are located in Everett,

¹ "Crucial Committed Competitive", Boeing Commercial Airplanes, 2003, pg.7.

² "Crucial Committed Competitive", Boeing Commercial Airplanes, 2003, pg.13.

Washington (777, 767 and 747), Renton, Washington (737, 757) and Long Beach, California (717).

In 2004, the total company revenue (Defense and Commercial) is USD 52.5 billion with an operating income of USD 2.0 billion and an operating margin of 3.8%. In 2003, the total revenue for Boeing Commercial Airplanes is USD 22.4 billion.³ In the fourth quarter of 2004 alone, the revenue for Boeing Commercial Airplanes is USD 5.4 billion. Boeing Commercial Airplanes delivered 285 airplanes, and won 126 orders and commitment from eight airlines for the new 787 in 2004.⁴ In 2002, Boeing Commercial Airplanes purchased almost USD 10 billion worth of goods and services from an estimated 5,580 companies across the US and USD 13.5 billion in goods and services from approximately 9,400 companies worldwide.⁵

Traditionally, Boeing has dominated the commercial airliner market, as reflected by the fact that 76% of the jets in the air today are Boeing planes.⁶ Its short-to-medium range 737 has been the best-selling jetliner of all time. Its jumbo jet 747 has also dominated the twin-aisle, long range market since her introduction in 1968. In 1989, Boeing added the twin-engine, highly efficient and innovative 777 to its airplane family and the 777 quickly became one of the best selling airplanes in the medium-to-long range market.

- **Airbus Industries**

Airbus Industries was established in 1970 as an airplane manufacturer. In 2001, an European consortium of French, German, and later Spanish and U. K. companies,

³ “Annual Report”, The Boeing Company, 2003.

⁴ “Fourth Quarter and Full Year 2004 Performance Review”, The Boeing Company, February 2, 2005.

⁵ “Crucial Committed Competitive”, Boeing Commercial Airplanes, 2003, pg.56.

⁶ “Crucial Committed Competitive”, Boeing Commercial Airplanes, 2003, pg.2.

called Aeronautic Defense and Space Company, was formed and became the majority owner of Airbus. Its two key manufacturing facilities are located at Toulouse, France and Hamburg, Germany, with subassembly locations all over Western Europe.

In 2004, Airbus delivered 320 aircrafts and attained the No. 1 market position in terms of deliveries for the second year in a row. Its total revenue is 20 billion euros in 2004. In 2001, Airbus has spent 14.1 billion euros in procurement all over the world, purchasing from more than 1,500 contractors in more than 30 countries.⁷

A series of successful new model launches by Airbus has enabled it to rise from relative oblivion in the airliner business to become one of the key players in the industry today. For instance, the introduction of the A320 family of aircraft in 1984 was a major success for Airbus. The A320 family's optimized cabin cross-section – the widest single-aisle fuselage on the market – sets new standards for passenger cabin flexibility in this segment. Featuring the most modern fly-by-wire technology available on any single-aisle aircraft, the A320 family provides operators with the highest degree of commonality and economy for aircraft in the 100-220 seat category.⁸ More recently, in 2000, the new “double-decker” A380 was launched, which promises to offer 10-15% lower operating cost, 10-15% more range, lower fuel burn, less noise and lower emissions than its Boeing jumbo counterpart 747-400.

- **Embraer**

Based in Sao Jose dos Campos, Brazil, Embraer was founded in 1969, as a government initiative and was privatized in 1994. Currently, Brazilian interests (investment conglomerate Bozano Group and pension funds PREVI and SISTEL) control

⁷ http://www.airbus.com/procurement/facts_n_figures.asp

⁸ http://www.airbus.com/media/a320_family.asp

60% of the voting shares and a leading group of European aerospace companies (Dassault Aviation, EADS, Snecma and Thales) owns another 20%.⁹

In 2003, Embraer's net sales amounted to USD 2.1 billion, with a net income of USD 136 million. In the first three quarters of 2004, its net sales increased to USD 2.49 billion with a net income of USD 297 million. Embraer delivered 101 jets in 2003 and 148 jets in the first three quarters of 2004. It currently employs 14,500 people, with 95% of them based in Brazil. It was Brazil's largest exporter from 1999 to 2001 and the second largest in 2002 – 2004.

Traditionally, Embraer's well established regional jets family, Legacy – Legacy Executive, Legacy Shuttle and Legacy Shuttle HC, represents its core business in corporate aviation. Recently, Embraer has moved to increase the size of the jets it manufactures, expanding its customer base from mainly corporate and private customers to commercial airlines. Embraer's emerging commercial jetliner business is focused on the 70 to 110 seat market, based on what Embraer calls the "Rule of 70 to 110".¹⁰ The observed trend is that mid-range aircraft (120 to 150 seats) with too many seats are flying smaller demand routes, while expanding regional markets are pressing regional jets (below 50 seats) to carry more passengers more frequently. Embraer has thus sought to find its niche in the equipment gap in the 70 to 110 seat segment, a range for which an efficient aircraft family did not exist. This approach has been highly successful, as evident from the popular demand of its E170/190 family jets by low-cost domestic airlines, such as Jet Blue.¹¹

⁹ <http://www.embraer.com>

¹⁰ <http://www.ruleof70to110.com/main/index.html>

¹¹ "JetBlue Airways Orders 100 EMBRAER 190 Aircrafts, with options for an additional 100", June 10, 2003. <http://www.jetblue.com/learnmore/pressDetail.asp?newsId=179>.

B. Industry Characteristics

It is very important to first understand the key characteristics of the industry before we can clearly analyze the industry dynamics¹². The following sections detail the relevant industry characteristics.

- **Product & Market**

Aircraft orders are extremely cyclical. As illustrated in the popular beer game¹³, delays in the supply chain, especially when the lead time is as long as what is typical in the aircraft manufacturing industry, can be very costly. The long lead time in current production is a result of the complexity of manufacturing processes and highly customizable parts, which in turn stem from a fairly heterogeneous demand. Airlines have different needs for different routes and schedules. They also have varied preferences for features, as well as for the degree of flexibility and capability for customization.

It is also important to note that whereas the brand is relatively less important for commercial aircraft; purchase decisions by airlines are more often impacted by the existing maintenance crew and flight crew, as any training costs incurred often represent a significant percentage of the operating costs. Consequently, the cost of switching from one airplane manufacturer to another can be prohibitively high, depending on the customer's existing fleet composition.

¹² Concepts taken from course 15.912 Technology Strategy by Rebecca Henderson, Spring 2005

¹³ The beer game is a logistics game developed at MIT. It is widely used in many business schools as a tool to explain the key fundamentals in operations management. <http://beergame.mit.edu/default.htm>

- **Cost Structure**

The cost structure of commercial aircraft manufacturing can be characterized by high fixed costs, and relatively marginal production costs. Labor costs are kept high by the union contracts in both Boeing and Airbus. Production operates at a high minimum efficient scale.¹⁴ .

- **Technology**

Technological innovation has been the key driver for product differentiation, although most of the innovations in recent years reside in systems and components that are outside of the manufacturer's domain, such as in avionics and flight control systems. Over the past few years, manufacturers have tried to differentiate themselves by leveraging more significant technological advances, for instance, Boeing's composite building materials for its new 787 model and Airbus' "double deck" design for its A380.

- **Post-September 11 Civil Aviation**

The impact of the terrorist attacks on September 11, 2001 on the civil aviation industry is highly detrimental. According to ICAO¹⁵ preliminary estimates, the world's scheduled airlines lost USD 11.9 billion in 2001, more than half of which – USD 7.4 billion – was shed by the 10 US major airlines. In comparison, the worldwide airline industry earned an estimated USD 3.3 billion in 2000. Revenue fell 7.1% to USD 305.3 billion in 2001 while operating expenses dipped only 0.5% to USD 316.2 billion. World

¹⁴ Minimum Efficient Scale (MES) is the output for a business in the long run where the internal economies of scale have been fully exploited. Aircraft manufacturing has a high minimum efficient scale since it requires high fixed cost to start operation and it takes high production volume to fully exploit the full economies of scale potential. <http://www.tutor2u.net/economics/content/topics/buseconomics/mes.htm>

¹⁵ ICAO - International Civil Aviation Organization

airline traffic (RPKs¹⁶) dropped 3% in 2001 – the first year-over-year decline since 1990-91.¹⁷

In addition to plummeting revenue, September 11 also brought additional concern with the security of flying, which heightened airline security and increased insurance costs. Airlines are estimated to spend up to \$30,000 to transform each of their cockpit doors into miniature bank vaults. The emergency counter-terrorism bill imposed a 30% tax on domestic ticket prices.¹⁸ Overall industry insurance premium increased by USD 2 billion. Rising fuel and labor costs only worsened the problem.

The cash-strapped airlines in the post-September 11 era were compelled to revise their vision and strategy on managing and acquiring their fleet. With huge up-front investment and long payback periods, fleet acquisition is among one of the most important strategic decisions airlines need to face. It affects their financial position, the operation costs, and their ability to serve specific routes. For example, a wide-body long-range 747-400 aircraft costs as much as USD 200 million, and a narrow-body 150-seat plane costs about USD 35-50 million, and both will impact the balance sheet (straight line depreciation) for at least 10 to 15 years.¹⁹ After September 11, the “ideal” payback period on a new aircraft shortened, since the airlines could no longer afford enormous assets in early depreciation cycles tied up on their balance sheet. As a result, in addition to traditional fleet acquisition, many airlines began to look into other options, which include leasing, power-by-the-hour (pay for service), modification of existing aircrafts

¹⁶ RPK - Revenue Passenger Kilometers

¹⁷ “A Year Not Soon Forgotten”, Air Transportation World, Jul 2002,

¹⁸ “Impact of September 11 on Air Transportation”, lecture notes from course 16.71J The Airline Industry, by John Hansman, MIT International Center for Air Transportation, Sept 11, 2002.

¹⁹ “Airline Planning Processes: Fleets and Routes”, lecture notes from course 16.71J The Airline Industry, by Peter Belobaba, Oct 2, 2002.

and conversion from freighters to passenger planes. On the other hand, the existing excessive capacity also increases the price elasticity on new fleet purchases, which resulted in bidding wars between aircraft manufacturers, driving prices down to marginal cost.

Minimizing operating costs also becomes paramount. The success of low cost carriers, as demonstrated by Ryan Air and EasyJet in Europe, and Southwest and Jet Blue in the US, intensifies the pressure on ticket prices for traditional carriers, causing them to turn to cost control in order to stay competitive. Apart from the increasing reluctance and delay in fleet purchase and upgrade, traditional airlines also responds by reducing onboard food services and amenities, increasing luggage restrictions, reducing schedules and eliminating less profitable routes. In order to minimize operating costs, airlines also seek to find the “exact fleet fit” for specific routes in order to maximize average load factor per flight.²⁰.

C. Industry Dynamics

- **Innovation and Technology**

In the early years of aviation in the 1900s, many small aircraft companies were set up. Among them, are the world’s first aircraft company founded by Charles and Gabriel Voisin to build custom planes outside Paris, France. The first US airplane company was founded by Glenn Curtiss in Hammondsport, New York. The first scheduled air service began in Florida in 1914, across Tampa Bay. Curtiss’ design made the 18-mile trip across Tampa Bay in 23 minutes, a considerable improvement over the two-hour trip by

²⁰ “Load Factor” is the percentage of seats that is generating revenue on any given flight. Airliner’s profitability is highly sensitive to this metric.

boat or the 12-hour trip by rail. The plane accommodated one passenger at a time, and the company charged a one-way fare of \$5.²¹ At that time, flying was a major technological innovation, a disruptive technology that revolutionized transportation.

In mid-1927, Boeing started to produce the Model 40A passenger/mail plane. By 1954, the dominant design of the modern commercial jet was created – Boeing’s 707. Although intended as a military tanker, the 707 revolutionized commercial aviation, cutting intercontinental travel time almost in half and bringing airfares within the financial reach of more people. The 707 gave Boeing a competitive advantage it has never lost.²²

Since then, Boeing has monopolized commercial aviation until the 1990’s when Airbus began to gain a foothold in the airplane market with its introduction of the A320 in 1984. The two companies have since been a long standing duopoly in commercial aircraft manufacturing. Figure 1²³ shows the key developments in the duopoly since the 1950s.

1950s	Boeing 707, introduced in 1958, launches the jet age. It was expensive, but its speed (doubling that of piston-engine airliners) made it successful.
1960s	Boeing introduced the 737 in 1967. It became the best-selling and longest-running airliner in production. The jet has since undergone two extensive makeovers in order to maintain its competitiveness.
1970s	Boeing’s iconic 747, introduced in 1970, was double the size of the next biggest airliners. Upstart Airbus produced its first commercial jet, the A300 – the first twin-aisle, twin-jet airliner, but was not popular enough to pose a threat to Boeing.
1980s	In 1982, Boeing’s 767 became the first long-range airliner to fly transoceanic flights with just two engines. The Airbus launched the A320 in 1987, the first highly automated, fly-by-wire aircraft.
1990s	In 1993, Airbus introduced the A330 and A340, similar but larger versions of the A320. In 1995, Boeing delivered the 777, a versatile, fly-by-wire jet.
2000s	Airbus launched the double-decker A380 in 2000. In 2002, Boeing terminated the Sonic Cruiser project. Subsequently, Boeing launched the 787 program (formerly known as 7E7) which will go into service in 2008.

Figure 1 Key Events in the Duopoly

²¹ <http://www.geocities.com/CapeCanaveral/4294/history/>

²² <http://www.boeing.com.au/History/boeing.html>

²³ “Boeing, Boeing, Gone?”, Popular Science, Jun 2004.

Since the emergence of the dominant design of the modern commercial jet, the industry has experienced a series of incremental innovation, including improvements in systems, structure, materials and interior designs. All these subsequent incremental technological improvements are based on the current dominant design. Using the innovation “S-curve” analysis²⁴, the current commercial jet age has reached maturity – the top of the S-curve. Figure 2 shows the S-curve illustrating the relationship between performance and time. There has yet to be another radical innovation comparable to that of the modern jet design in 1954. Only when such a groundbreaking innovation arises will the industry experience a disruption and jump on the next “S-curve.”

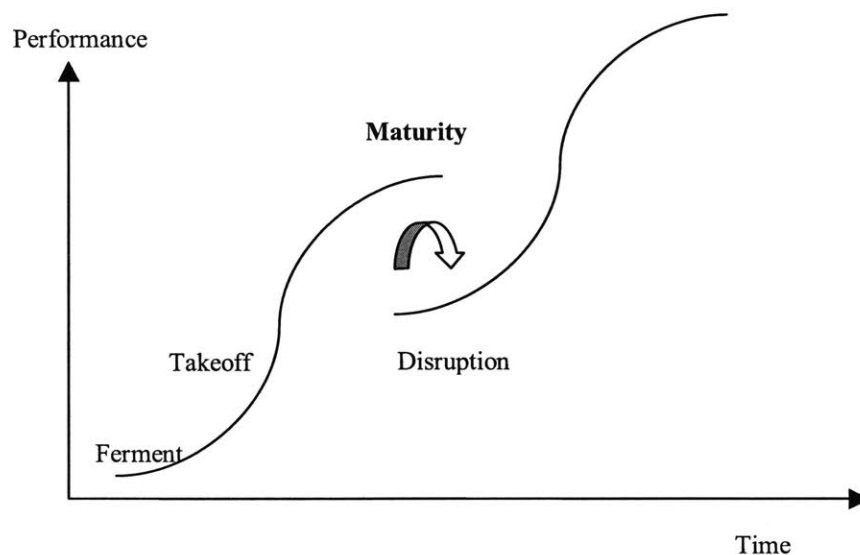


Figure 2 Technological Innovations in the Modern Commercial Jet Age

²⁴ The “S-curve” is a tool used by many business strategists to understand and forecast trends in technology driven businesses. The bottom of the S-curve is a period of ferment when many small firms test various technologies. The steep slope represents the emergence of the dominant design and occurrence of the industry shakeout. The top of the S-curve represents a period when the existing dominant design reaches maturity. The industry will start on another S-curve if another dominant design emerges and overtake the current one. Concept taken from course 15.912 Technology Strategy by Rebecca Henderson, Spring 2005.

- **Strategic Analysis – Porter’s Five Forces**

Using the Porter-Five Forces²⁵ framework, we can further analyze the industry by understanding the key forces behind the industry dynamics. As illustrated in figure 3, the five key forces are buyer power, supplier power, barriers of entry, substitutes, and rivalry.

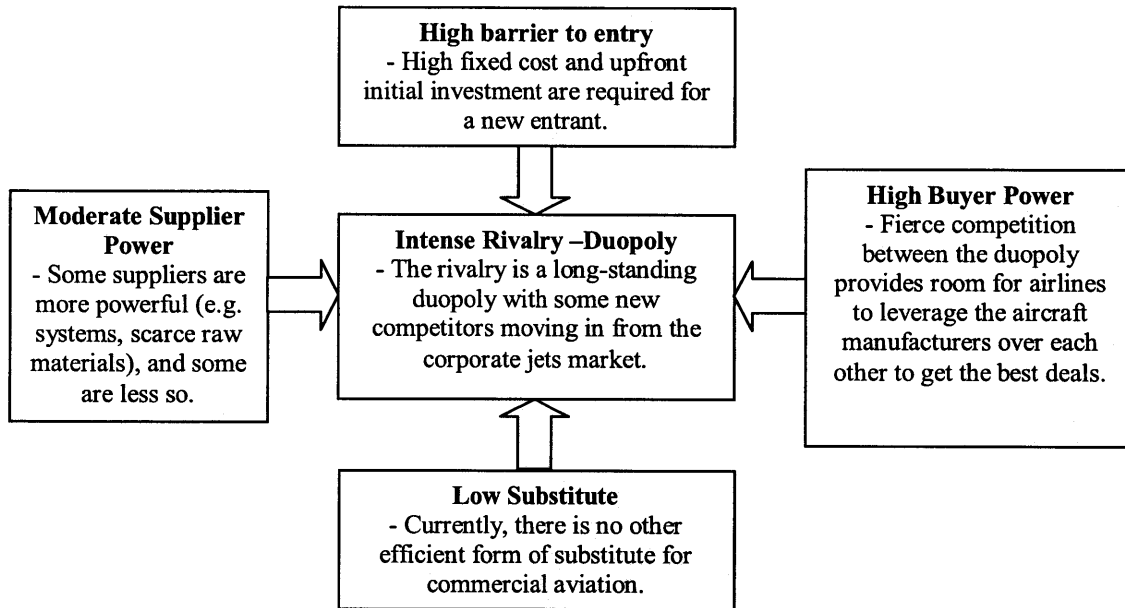


Figure 3 Industry Structure in Porter’s Five Forces Framework

1. Rivalry and Buyer Power

The duopoly between Airbus and Boeing is in intense competition. Beyond general business economics, other factors are also part of the equation, such as national pride and job security. The intense competition drives down prices, making both companies more vulnerable during negotiations with airlines. The over-capacity in the industry also gives the airlines a lot of bargaining power to play the two rival companies off against each other. After September 11, owing to the difficult financial situation in the

²⁵ Saloner, Shepard and Podolny. “Strategic Management”, 2001. pg. 124-127.

airline industry, businesses are scarce, which further contributes to the intense competition.

2. Barriers-to-Entry

While there is generally high barrier of entry, the barriers are not prohibitively high for companies who are already in “adjacent businesses”. For example, Embraer, the Brazil based company which used to build only corporate jets, managed to produce commercial jets with more than 100 seats, putting themselves in direct competition with the 737 and the A320. Their entrance of the E170/E190 into the market has been extremely successful, as evident from their backlog orders worth USD 10.1 billion in 2004.²⁶ Therefore, while the high costs of starting an aircraft-making business from scratch might create high barriers of entry in general, companies in adjacent businesses do not face such high barriers due to their existing infrastructure.

3. Supplier Power

Supplier power varies with the component or material supplied. For instance, suppliers who sell highly sophisticated and expensive components, such as, avionics and flight deck controls, tend to command more power than other suppliers. Moreover, suppliers who provide scarce and critical materials, such as, aluminum, also possess more power than other suppliers.

4. Substitutes

There is no currently known mode of transportation that offers an efficient substitution for aviation. Other current modes of transportation do not offer the same benefits, such as accessibility and travel time, as commercial aviation. There are a few markets in which some substitution possibilities have emerged. For example,

²⁶ <http://www.embraer.com>

immediately after the September 11 incident, many passengers opted to travel between various cities in the Northeast US corridor by rail.

- **Positioning for the Future**

- 1. Boeing: the 787 program**

In late 2002, Boeing Commercial Airplanes' Chief Executive Officer, Alan Mullaly announced the cancellation of the Sonic Cruiser program. Instead, he redirected the company's focus to developing the 7E7 (later renamed 787), which is designed to capture the potential in the so called "middle of the market".

The "middle of the market" is the segment in which existing airplanes such as the 757, 767, A300/A310 and A330 currently serve. These models can fly approximately 3,000 to 6,500 nautical miles and carry passenger loads of approximately 180 to 250 people in both single- and twin-aisle configurations. The ideal airplane to best serve the "middle of the market" should be able to operate equally efficiently for distances shorter than 3,000 nautical miles or more than 7,800 nautical miles. If an airplane can fly distances equivalent to a 777, carry a 767-level passenger load, and get passengers to their destinations quicker, it will allow airlines to offer new nonstop services to more destinations – profitably.²⁷

The motivation for the 787 is to offer the ideal airplane for the middle market. It is designed to offer a 20% increase in fuel efficiency, an additional 60% in cargo capacity, a technology enabled aircraft interior, and most importantly, lower overall operating costs for the airlines. Figure 4 illustrates the middle market segment among other aircraft segments.

²⁷ "Finding the "Sweet Spot" in the Market – Maximizing the Middle", Boeing Frontiers, Mar 2003, pg. 14.

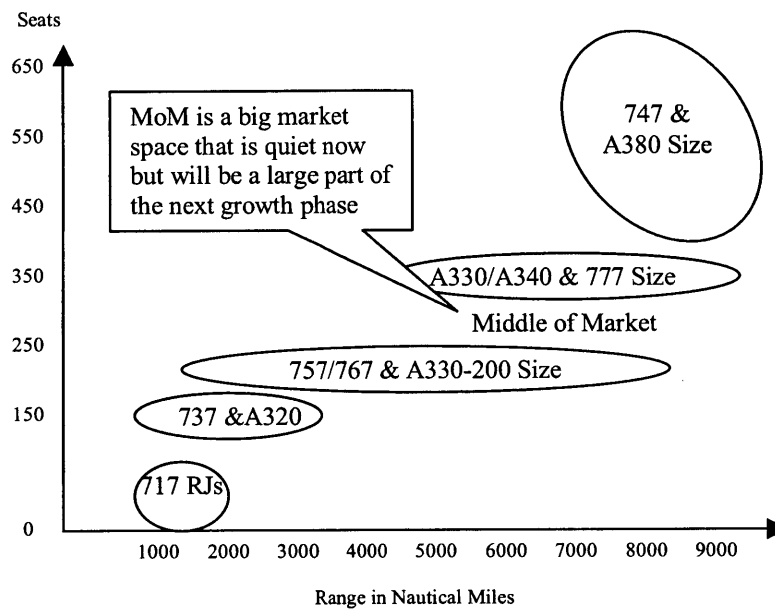


Figure 4 What is the Middle of the Market (MOM)?²⁸

2. Airbus: The A380 and A350

The long-haul, jumbo jet market has long been dominated by Boeing's legendary 747. In 2000, Airbus launched the first double deck commercial jet – A380, which completes the Airbus airplane family to serve all markets covering all nautical mile range. Figure 5²⁹ provides an overview of the Airbus airplane family.

²⁸ "Finding the "Sweet Spot" in the Market – Maximizing the Middle", Boeing Frontiers, Mar 2003, pg. 14.

²⁹ <http://www.airbus.com>

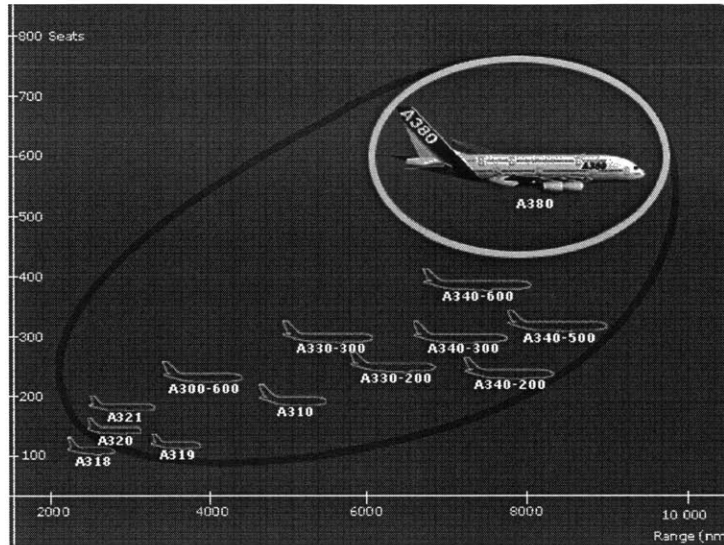


Figure 5 Overview of the Airbus family³⁰

The first A380 will enter service in 2006. It will seat 555 passengers in a typical three-class interior layout. With increased capacity, Airbus estimates that the A380 has the potential to increase an operator's return by as much as 35%, resulting in 15-20% lower operating costs than any competitor aircraft.³¹ The A380 will provide passengers with luxury options never enjoyed aboard a commercial airliner. Airbus envisions that airlines will use the ample space aboard the long-haul plane for cocktail lounges, waterfall fountains and private suites that serve as in-air bedrooms and business meeting areas. Airbus believes that the A380 is the right-sized airliner in light of the increasingly congested skies and crowded international hubs. Airbus hopes to sell more than half of its super-jumbos to airlines in developing nations in Asia, where a growing middle class does not fly very much now but has become wealthy enough to do so.³²

³⁰ <http://www.airbus.com>

³¹ http://www.airbus.com/product/a380_economics.asp

³² "Hopes Big Plane Will Take Off; Behemoth Designed to End Reign of Rival Boeing's 747", The Washington Post, Dec 10, 2004.

At the end of 2004, Airbus planned to roll out the A350, a derivative of the current A330. It is designed to compete head to head with Boeing's 787 in the medium-to-long range market. A350 will have the same cockpit and similar on-board systems to its existing A330 jet but will weigh 8.8 US tons less, thus allowing for heavier engines. The new engines, to be supplied initially by General Electric Co., will benefit from technologies developed for the 787.³³ Airbus predicts that the operating cost of A350 will be 6-7% lower than that of the 787 and can enter service in 2010 in two configurations.

3. The Future of Air Travel

There is ample literature, from academic journals to general business publications, which forecast the dynamics of the future of air travel. The development of the 787 is an indication that Boeing believes the future of air travel will be primarily based on frequent, point-to-point travel between most destinations. On the other hand, Airbus develops the A380 based on the belief that the crowded air space will put pressure on frequent schedules, and the future of flying will primarily be a hub-and-spoke system.

Understandably, airlines have little incentive to put either aircraft manufacturer out of business. Fierce competition between Airbus and Boeing affords the airlines enormous power in fleet purchase negotiations. Therefore, most airlines would prefer to maintain a mixed fleet of aircrafts from each manufacturer. For example, as of 2005, Cathay Pacific's current fleet consists of 41 planes from Airbus (18 of A340 and 23 of A330) and 34 planes from Boeing (19 of 747 and 15 of 777)³⁴. The A330 and A340 are used primarily for shorter flights while 777 and 747 are used for longer, trans-Pacific flights. Therefore, with both manufacturers now offering aircrafts that service all markets,

³³ "Airbus Gets Green Light to Launch 7E7 Challenger", Associate Press Worldstream, Financial News, Dec 10, 2004.

³⁴ <http://www.cathaypacific.com/intl/inflight/fleet/0,,00.html>

airlines can choose planes from different manufacturers for different routes. For example, Airbus' A380 would be an attractive candidate for a few major trans-Pacific routes that generally have high load factors but less frequent schedules. Meanwhile, Boeing's 787 would be the ideal aircraft to fly trans-Atlantic routes on more frequent schedules.

On the other hand, there are also cost benefits of maintaining a single aircraft fleet, as evident by the success of Southwest, which keeps maintenance cost low with its entire fleet of Boeing 737. In fact, this approach is practiced by many low cost carriers. However, such a strategy would only apply to low cost carriers, which typically offer a limited set of routes. Traditional airlines, which serve many worldwide destinations, cannot maintain a single aircraft fleet, which is too restrictive in terms of range and passenger load.

As a result, most airlines will buy different models from both manufacturers to serve different routes. Moreover, now that both manufacturers offer products that service all market segments, competition will intensify and further drive down prices. In such competitive dynamics, the manufacturers can only get ahead if they focus on reducing cost to improve their bottom-line. If they have a cost advantage over their rival, they will be able to offer competitive prices and still maintain a healthy margin. Therefore, in the future, sustainable competitive advantages will not only come from superior design and engineering of the aircraft, but also from more cost-effective manufacturing and supply chain management. The next section will provide a closer look at how both manufacturers can leverage cost-cutting opportunities in their supply chain to obtain a sustainable competitive advantage.

II. Supply Chain Analysis

A. Literature Review

Supply chain issues in the aerospace industry have been extensively studied in many academic and business publications. In academic circles, the aerospace industry is often used as a research example to illustrate how an industry with slow clockspeed and heavy inertia respond to new supply chain practices. For example, in an article on recent supply chain reforms for many manufacturers³⁵, Anselmo suggested that many executives and consultants consider the aerospace supply chain years behind other industries such as automobiles, consumer electronics and construction. He attributed this trend to the industry's lagging adoption of information technology, which creates challenges for the members of supply chain to share information and work closely with one another.

Fine, in his book "Clockspeed"³⁶, discussed extensively Boeing's decision to outsource many of its work to its suppliers, in particular, wing manufacturing to Japanese manufacturers. Using the double helix framework introduced in his book, Fine concluded that while outsourcing is a natural outcome for the aircraft industry, Boeing also needs to consider the long term impact that the outsource decision has on the company's core capability. Fine also used the Boeing 777 as a prominent example to illustrate the importance of concurrent engineering in products with integral product architecture. He suggested that the best place to be is on the diagonal – modular product architecture be

³⁵ Anselmo, Joseph. "Supply Chain Reforms Too Late for Many Manufacturers", Aviation Week and Space Technology, Nov 14, 2004.

³⁶ Fine, Charles. Clockspeed, 1998.

supported by a modular supply chain design, and integral product architecture supported by an integral supply chain design (see section B).

This thesis will draw extensively on Fine's work and further discuss many of these supply chain challenges in greater depths and how they manifest themselves in execution. In particular, specific examples will be drawn from Boeing 787 new aircraft development in chapter III.

B. Supply Chain Dynamics

- **Value Chain Overview**

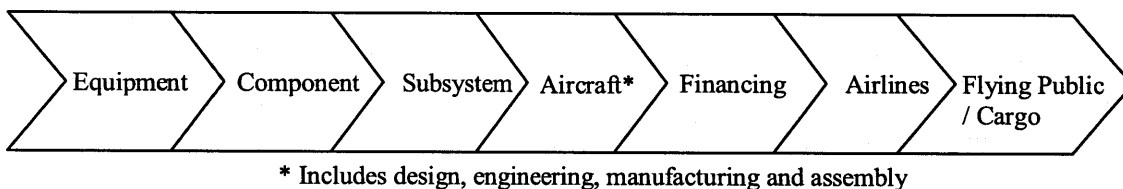


Figure 6 Value Chain for Civil Aviation

Figure 6 shows the major components in the entire value chain for civil aviation. Traditionally, aircraft manufacturers perform most of the design, engineering, manufacturing and assembly of the aircraft. For instance, even today, Boeing manufactures and assembles the wing for some sustaining programs. The manufacturers only outsource some critical subsystems beyond their core competence, such as avionics and software. However, as the world of business becomes increasingly global and organizations become increasingly complex, many companies seek outsourcing options, so as to focus on their core competence while leverage outsourcing to reduce costs. In

fact, the current operating model at Airbus is heavily decentralized and modularized. I will discuss this in further details in a later part of this section.

- **Make vs. Buy**

While it is widely believed that most companies should keep in-house their core competence and outsource non-core activities, one needs to be aware of the dependency dynamics³⁷. When an organization makes a sourcing decision, whether internal or external, it is planting a “capability seed” that has the potential to grow into a valuable and powerful organizational competency.³⁸ For instance, by outsourcing to Japanese aerospace suppliers, Boeing planted the seeds of various competencies that grew under their own power over time, and eventually went beyond the ability of Boeing to control them. As Boeing no longer manufactures their wings, it might lose their knowledge and know-how in the long term. Meanwhile, Japanese aerospace suppliers will develop so much expertise that their proficiency in wing design and manufacturing will take on a life of its own, turning the table around and allowing them to gain much more power in its relationship with Boeing. As illustrated in Figure 7, Boeing’s subcontracts had a positive impact on the size and technological capabilities of the Japanese suppliers, which, in turn, increased Japanese industry autonomy and ultimately the ability of that industry to demand more critical work, enabling them to win more contracts.³⁹

³⁷ Fine, Charles. Clockspeed, 1998. pg. 159-160.

³⁸ Fine, Charles. Clockspeed, 1998, pg. 159.

³⁹ Fine, Charles. Clockspeed, 1998, pg. 162-163.

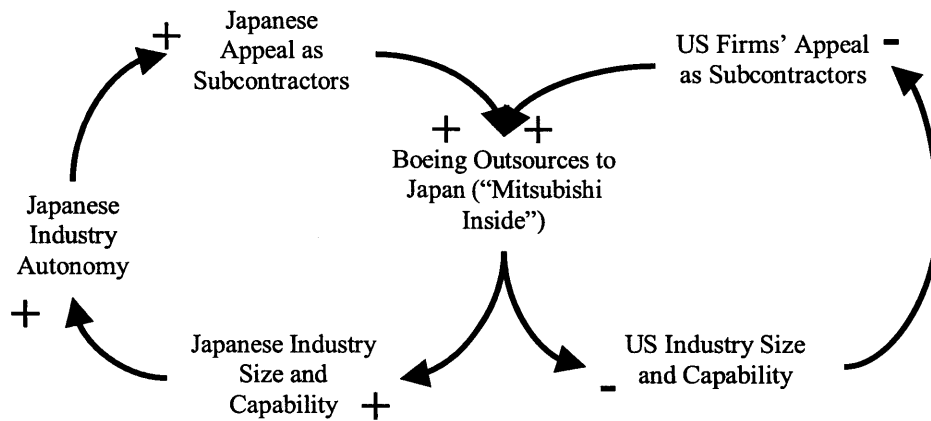


Figure 7 Boeing's Dependency Dynamics Capability Outsourcing and Technological Dependency

Depending on the actual component and function that is outsourced, the dependency would have a different impact. For instance, outsourcing component fabrication would have a lesser dependency effect than outsourcing airframe design and assembly on which the overall system performance highly depends.

One would argue whether companies can engage in outsourcing and yet maintain its technical expertise and know-how in the product, thereby breaking the dependency dynamics cycle. In fact, many companies try to keep their expertise in-house by duplicating work and establishing additional levels of oversight processes inside the company to ensure keeping the know-how in-house. Such strategies add additional layers of reporting and supervision structure, which are unnecessary for execution and inevitably increase project costs. Therefore, the additional cost increase might outweigh the cost benefits from engaging in outsourcing in the first place.

- **Integration vs. Disintegration**

As shown in figure 8, the dependency dynamics provides some insights on the evolution of the supply chain. The “double helix” is a framework which outlines how industry structure and product structure evolves from integral to modular and back.⁴⁰ It explains why firms would engage in a constant cycle of integration and disintegration, and of moving processes in and out of the company. The speed at which the company engages in this cycle heavily depends on the clockspeed at which the industry operates. For example, the automotive industry went through the double helix two to three times when the aerospace industry went through it once.

Using this framework, we can make some predictions on how the industry will evolve. Currently, as evident by the increasing amount of outsourcing activities, the aircraft manufacturing industry experiences pressure to disintegrate and modularize the supply chain. As a result, component manufacturers with faster clockspeed, such as control software and system electronics providers, stand to benefit significantly from modularization, since it enables much easier and quicker product upgrades without significant impact on overall integration.

⁴⁰ Fine, Charles. Clockspeed, 1998.

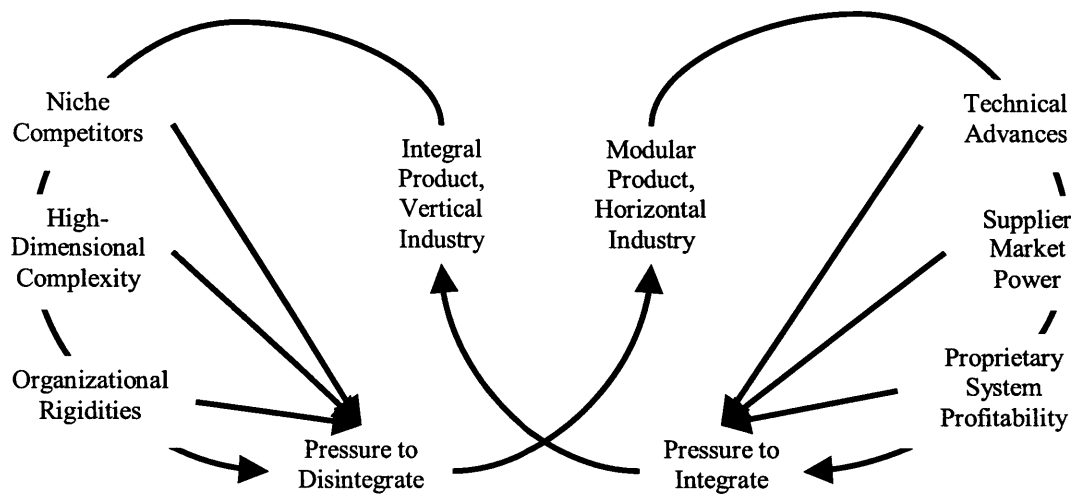


Figure 8 The Double Helix – Illustrating How Industry/Product Structure Evolve from Vertical/Integral to Horizontal/Modular, and Back.

- **Airbus' Modularized Supply Chain**

Leveraging its consortium structure, Airbus developed a well-run and highly modularized supply chain. Since Airbus is essentially a consortium of companies with each individual company or subsidiary needing to own its share of the responsibility in the airplane production process, Airbus modularized their plane design so that each company can conveniently own a piece of the work, with all the pieces then being seamlessly integrated. Furthermore, Airbus developed a common platform on which all planes in its airplane family operate. Based on this common platform, each company in the consortium specializes on one set of components for the entire airplane family. Such specialization allows individual companies to develop an expertise in their respective components, and facilitates product innovation for new generations of airplanes.

Figure 9 illustrates the various factors enabling Airbus' modularized supply chain. Due to stable long term relationships with its partners and suppliers, many of them being

companies in the consortium, Airbus is free to allow these companies to build a high level of expertise around their respective sets of components. With such high level of product expertise at the partners and suppliers, as long as clear contractual and collaboration terms are outlined, Airbus can be very hands-off in managing its suppliers and comfortable giving its partners high level of accountability. In addition, since most of these companies are located in Europe, their proximity greatly facilitates logistics coordination. With this supply chain design, Airbus only needs to develop competency in partnership management and large systems integration, in addition to design and engineering.

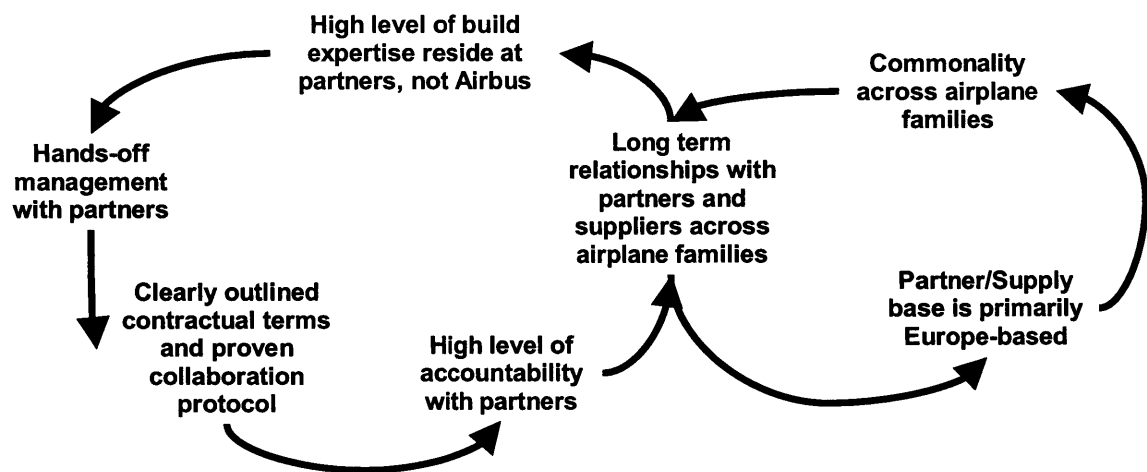


Figure 9 Airbus' Modularized Supply Chain

- **Alignment of Product and Supply Chain Architecture**

However, should a product with highly integrated product architecture, such as that of the modern commercial jet, be produced using a modularized supply chain? In his

book *Clockspeed*⁴¹, Fine argues that in essence, product and supply chain architectures tend to be mutually reinforcing. Therefore, product and supply chain architectures should be aligned; integral products should be developed by integral supply chains, and modular products should be built by modular supply chains.

As illustrated in figure 10, even in the same industry, firms can produce vastly different kinds of product and adopt different supply chain architectures, and be equally successful, as long as their product and supply chain architecture are aligned. As an example, consider the two automotive manufacturers, BMW and Chrysler. BMW products are among the highest performing luxury sedans in the world. Therefore, BMW sacrifices much in cost and development time in order to deliver the best possible performance in a highly integrated product. Few other car companies in the world could match BMW in performance, handling, and safety. Automotive critics regularly voted BMW's models the best cars in the world in their respective class.⁴² Such integrality in the product requires a highly integrated supply chain to ensure tight control of vehicle specifications and smooth interactions among all key subsystems.

⁴¹ Fine, Charles. *Clockspeed*, 1998.

⁴² BMW: The 7-Series Project (A), Harvard Business School Case Studies, Jan 3, 2002.

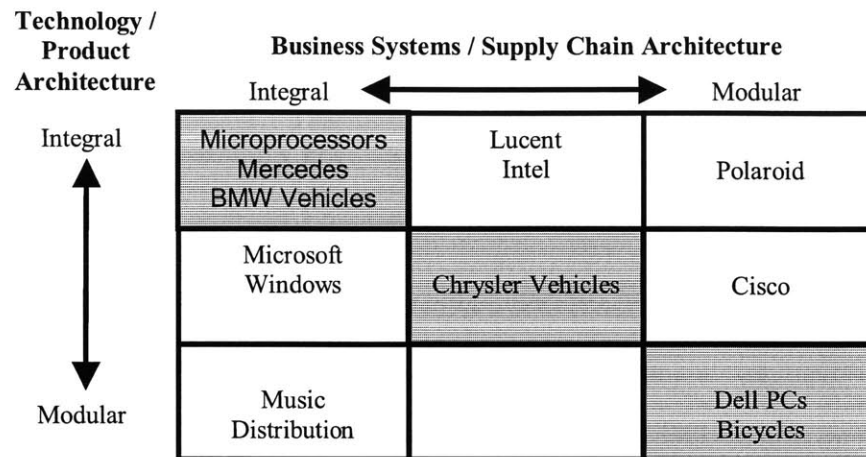


Figure 10 Interactions between Product and Supply Chain Architectures

On the other hand, Chrysler's strategy is to reduce the total time and cost required to develop and launch a new vehicle by outsourcing the development and integration of many automotive subsystems. Therefore, Chrysler focuses on designing cars that can be modularized for its supply chain. Such design puts Chrysler's product, and supply chain in alignment. By designing cars for a modularized supply chain with significant outsourcing, Chrysler is able to produce a variety of cars that are less expensive, with decent overall reliability and performance, at a price affordable for the mass market in a relatively short period of time.

Therefore, it is possible for different companies in the same industry to choose to produce products with different product and supply chain architectures, as long as the two architectures are aligned with each other.

III. Case Study: 787 Supply Chain Development

A. Introduction

- **The New Airplane – 787**

The 787 (formerly named 7E7) is a brand new airplane development program in the Boeing Company. Announced in 2002, the airplane is anticipated to be in service by 2008. Figure 11 outlines the key milestones of the program to date (*as of July 2004*).

Dec 2002	Alan Mulally, Boeing Commercial Airplanes president and CEO, announced that the company will focus its commercial product development efforts on a new super-efficient twinjet aimed at the middle of the market.
Jan 2003	A new senior leadership team was established for the 7E7 program.
June 2003	Composites were selected as the primary material for the 7E7 primary structure.
Nov 2003	Airlines representatives gathered in Seattle for updates on the 7E7 and are the first to tour the new 7E7 interior mock up.
Nov 2003	Boeing announced its selections of structural partners.
Dec 2003	The Boeing board of directors granted authority to offer the 7E7 for sale, clearing the way for the first formal sales offers.
Feb 2004	Boeing began to announce its systems partners for the 7E7.
April 2004	General Electric and Rolls-Royce were selected to provide engines for the program.
April 2004	Boeing launched the 7E7 with a record-breaking launch order for 50 airplanes from ANA (All Nippon Airways).

Figure 11 Key Milestones in the 787 Program⁴³

The new airplane offers an enhanced environmental performance (20% increase in fuel efficiency), up to 60% more cargo capacity, a dramatically different interior and improved customer flying experience (larger windows, wider seats and aisles, innovative lighting, better-controlled cabin pressure and humidity, and reduced noise level), and overall lower operating cost. In addition to product features, the 787 is also very different from the sustaining programs (other Boeing 7-series airplane program) in many different

⁴³ "Tomorrow in the Works", Boeing Frontiers, Jul 2004, pg. 14.

ways. Figure 12 outlines some of the key differences between the sustaining programs and the 787 program.

Existing Airplane Programs	787 Program
Thousands of options available per airplane	Hundreds of options available per airplane
Boeing manages hundreds of suppliers at all levels	Boeing deals with much fewer partners
Boeing defines end item configuration (except engines). Suppliers build end item per “Build-to-Print” model	Partners or associate partners define end item configuration (except engines). Partners define and build end item (not “Build-to-Print”)
Boeing manages the build configuration during the entire build cycle	Boeing manages overall large scale systems integration
Thousands of end items in final assembly	Much fewer end items in final assembly

Figure 12 Anticipated Differences between 787 and sustaining programs

The design of the new airplane is in line with the company’s overall strategy, which is to move up the value chain, to become a large-scale system integrator and to become a global company. For example, reducing the number of parts and leveraging its supplier network allows Boeing to move up the value chain more effectively, and to focus on large-scale system integration instead of manufacturing and fabrication. In addition, Boeing also hopes to develop expertise in large-scale system integration by focusing on managing the final assembly. Reducing product options allows easier product modularization and standardization, enabling Boeing to better leverage the suppliers’ and partners’ network.

- **The Challenge of *the New Partnership Structure***

In addition to having different product features, the 787 program is also the first program in which many new business processes and systems are put in place. The most fundamental – and the biggest – challenge is to execute the new partnership structure. Boeing has traditionally worked with a lot of suppliers who manufacture and design their subsystems and components. Therefore, the suppliers are not new to working with

Boeing. However, Boeing is revolutionizing its way of doing business with their suppliers in the 787 program. Instead of the old “supplier-Boeing” relationship, Boeing aspires to engage them as partners – who are working, learning, sharing risks, and succeeding together. Essentially, the partnership ties Boeing and their partners’ fate as one. This is a brand new concept, both to Boeing and to their suppliers. In the past, while they work very closely together, their relationship is still positioned at an arm’s length. Since Boeing is at the downstream in the value chain and ultimately it’s a “Boeing plane”, the company underwrites the product and “absorbs” all the shocks in the process. However, under the new partnership structure, their fates are tied.

In fact, the partnership concept is nothing extraordinarily groundbreaking. In other industries, such as automotive and computer manufacturing, similar partnerships have existed for decades. However, implementing such structure for a legendary aerospace company like Boeing is a revolution like no other. In fact, interestingly enough, the partnership structure does not only apply between Boeing and its partners, but also, within the Boeing Company. In current airplane programs, the company is organized into many functional divisions which operate like many distinctive units. However, Boeing is implementing a new organizational design to the 787 program. Instead of operating with functional units, the 787 program will be primarily driven by design-build teams.

In fact, Airbus has practiced a partnership structure for decades. For Airbus, establishing a partnership structure is a natural evolution. Since Airbus is essentially a structured consortium with many independently run subsidiary units, these subsidiary units essentially form a partnership structure. Therefore, for many years, Airbus has

designed their aircraft for standardization and modularization enabling a strong partnership network.

- **The Supply Chain Challenge**

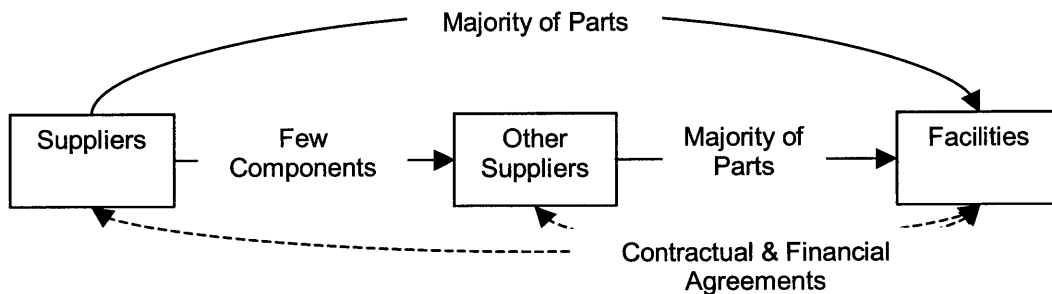


Figure 13 Supply Chain for the Sustaining Programs

Figure 13 shows a high level overview of current supply chain design for the sustaining programs. Most of the parts which Boeing directly contracts are delivered to Boeing facilities. There will be very few components which Boeing contracts to be drop-shipped to other suppliers' facilities.

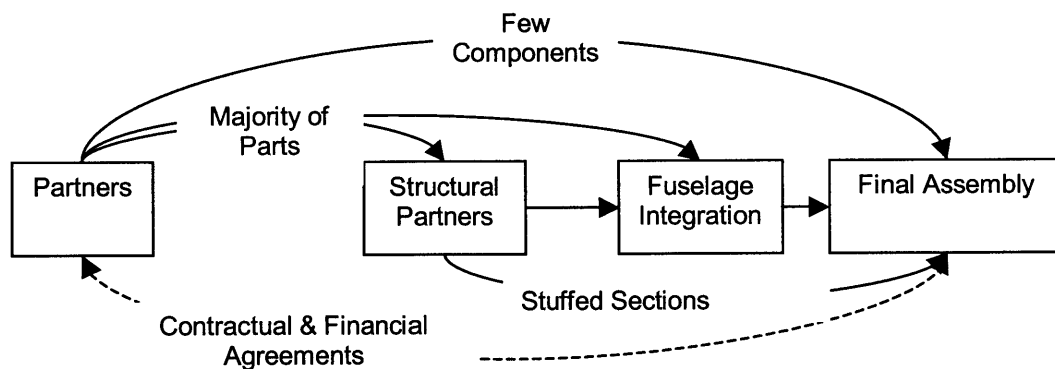


Figure 14 787 Supply Chain Design

However, as shown in Figure 14, in the 787 supply chain design, the majority of parts contracted directly by Boeing will be delivered to non-Boeing facilities. Under the new arrangement, Boeing establishes partnership agreements with a few key structural partners. The structural partners are responsible for designing and manufacturing their respective “stuffed sections” of the 787. “Stuffed sections” are essentially a section of the airplane with the structural elements (e.g. floors, beams), and electronic components (e.g. wires, sensors, systems) and sometimes even interiors (e.g. walls, carpets) fully installed. The few “stuffed sections” will then be connected and integrated during fuselage integration or final assembly. As an illustration, Figure 15 shows a picture of a stuffed section of a ship in the ship building industry.

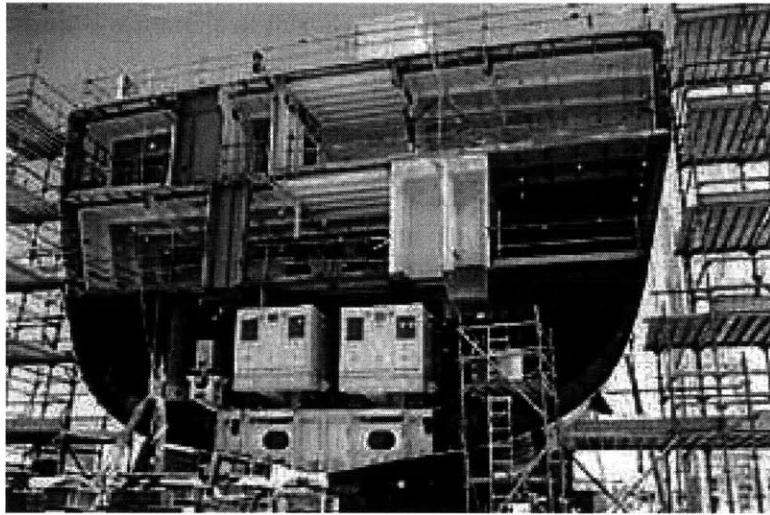


Figure 15 Stuffed Section of a Ship⁴⁴

At a high level, Airbus’ supply chain resembles that of the 787 program. However, instead of contracting the major of components directly with component suppliers, Airbus subsidiaries would instead set up those contracts themselves. This is

⁴⁴ Photo courtesy of Professor Daniel Whitney.

easier for Airbus since the subsidiaries are responsible for the same sections across all planes in the family, and they can leverage the commonality across all planes to set up long term contracts with their suppliers.

The new supply chain design poses some new challenges for Boeing. Two main issues are the coordination of ordering and scheduling, and quality management. Furthermore, since components will be shipped to structural partners all over the world for installation into the stuffed section, questions about whether or not such a build plan makes sense for all systems components arise. For example, inefficient situations may arise in which a systems component is shipped from the US to Europe for the often-trivial installation at the structural partners, and then the stuffed section is shipped back to the US for final assembly. It may have been more efficient to ship the systems component directly to the final assembly site in Everett, Washington, and to perform the simple installation there. However, one would have to consider whether such a scheme will affect the targeted 3-day production cycle at the final assembly site.

- **Key Research Questions**

The crux of the new supply chain design lies in Boeing's relationship with its suppliers, and in particular, how Boeing defines roles and responsibilities for its partners and suppliers. Such consideration needs to be put in place during the contract drafting and negotiation stage. I was privileged to have the opportunity to participate in the 787 program at this critical time when a lot of these contract terms are to be finalized. After spending time learning about the program and collecting data within and outside the company, I discovered that the impact on operation costs from the drop-shipped components is one of the most important challenges of the 787 program. Currently, since

drop-shipped components account for only a small portion of total components, any inefficiency in managing these parts can be tolerated without causing a detrimental effect to the overall operation cost. However, as the 787 program moves towards drop-shipping the majority of its components, any inefficiency in the current management system will become prominent and its cost impact will be amplified. Therefore, it is very important for the 787 program to anticipate these problems and put in place the necessary systems during the product and process development phase, in order to enable smooth implementation when production starts.

In order to put in place a set of processes that will be sustainable for the anticipated high volume of drop-ship components, the 787 program will need to address the following questions:

- How can the current ordering, scheduling, delivery and payment trigger processes be adopted for the 787 program? What needs to be changed?
How can Boeing adopt a less hands-on approach with its partners and yet maintain adequate visibility into the production and delivery of the components? What are the organizational barriers that need to be overcome in implementing the new processes?
- How can the current quality control and non-conformance management mechanisms be adopted for the 787 program? What needs to be changed?
How can Boeing ensure adequate quality control and efficiently manage non-conformance in the new supply chain design? Where will there be resistance in the organization and how can they be overcome?

B. Ordering and Scheduling

- **The Challenge**

In the sustaining programs, some materials and components that Boeing directly purchases are drop-shipped from component suppliers to structural partners for installation or further work. Compared to components that are procured by and directly delivered to Boeing facilities, these components go through a different procurement process. Figure 16 outlines the major steps in the current drop-shipped materials process.

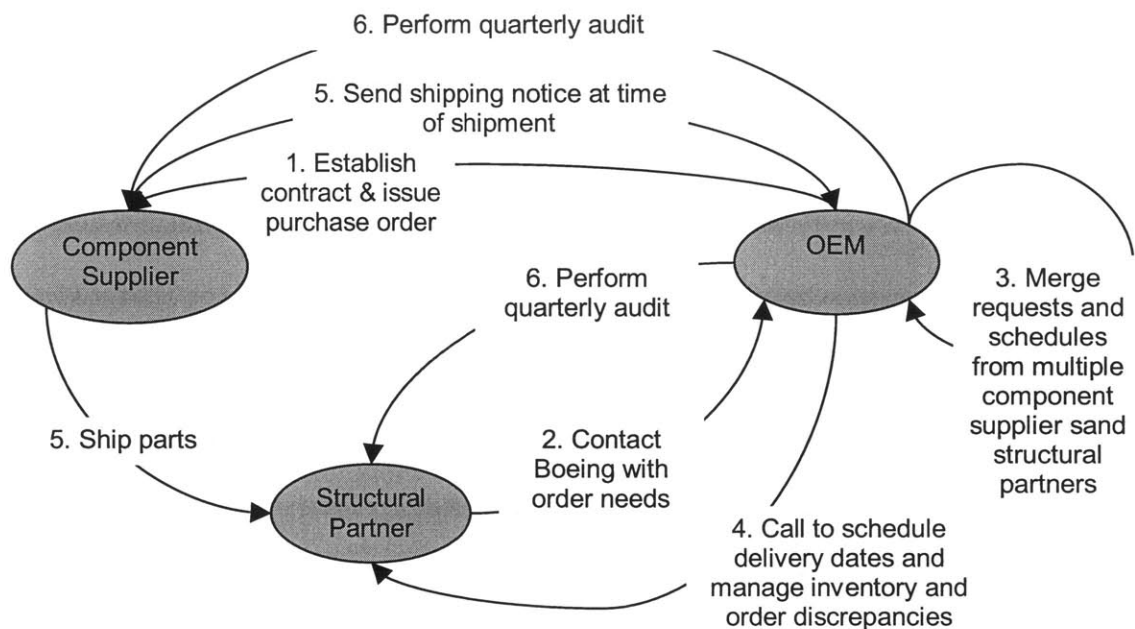


Figure 16 Drop-Shipped Components Management Process

First, Boeing sets up purchase order and long term purchase contracts with the component suppliers, as well as agreements with the structural partners. Boeing's supplier management department then merges schedules from various suppliers and partners and decides on shipping quantity and schedule based on the overall airplane

build and production plan. The supplier management department will then contact both the component supplier and structural partner for shipment and receipt. While the components are shipped from the component supplier, a shipping notice will be sent to Boeing. When the structural partner receives the shipment, a receipt notice will also be sent to Boeing. Every quarter, representatives from the supplier management department in Boeing will visit both suppliers and partners and perform an audit to manage discrepancy in inventory level.

Having the visibility into the procurement and shipping processes is very important for Boeing. It allows Boeing to track down and follow up with any orders, as well as handle quality, payment and delivery issues in the pipeline. However, the current process of merging schedules and requests from multiple component suppliers and structural partners as well as managing inventory discrepancies between suppliers involve primarily manual labor in the supplier management department. This is understandable, as the current system was designed and tailored for the sustaining programs. In sustaining programs, only a small number of components go through this procurement process, since most of the parts are directly shipped to Boeing facilities for assembly and the current resources in the supplier management department is sufficient to handle the load.

However, for the 787 program, there needs to be a paradigm shift, as the structural partners are now responsible for assembling the entire stuffed sections. As described above, many components, systems components in particular, need to be shipped to the structural partners for installation into the stuffed sections. Therefore, the load of components going through this process increases significantly. Unfortunately, the current process has limited capacity and is not designed to be very scalable. Therefore,

additional resources and changes are required to devise a procurement process that will work for the 787 program.

- **Competitive Benchmarking**

Since every subsidiary in the Airbus consortium operates like an independent company, each of them performs its own supplier management and procurement functions.⁴⁵ Therefore, unlike Boeing, very few components will be procured by a central authority to be drop-shipped to another location. Instead, each company will procure its necessary components to be used on its own facility. Therefore, the procurement transaction is very clear and simple. While Airbus might negotiate bulk-buy purchasing contracts for its subsidiaries, the transactional responsibilities reside with individual companies. Thus, the buyer company first establishes a purchase order with and provides a delivery schedule to a component supplier, and notifies the supplier when the parts is needed. Since only two parties (buyer company and component supplier) are involved, accountability and responsibilities are well aligned and easily traceable.

- **The Recommendation**

One key question to ask is what role should Boeing play in the ordering and scheduling process. In the spirit of the partnership structure for the 787, Boeing's role should evolve from that of an underwriter to that of a facilitator. For instance, in the event of discrepancies in the ordering and scheduling processes, Boeing should not take full responsibility and accountability. The current approach is a drain to the company's resources and most importantly, out of line with the spirit of the partnership structure.

⁴⁵ Data from Benchmarking Group, The Boeing Company.

On the other hand, Boeing wishes to continue to play a role in managing the interactions between partners and suppliers because it still owns the final design and integration of the aircraft upon delivery. Boeing can conceivably achieve this purpose by setting up and maintaining a virtual interface – a supplier portal – for communication between Boeing, partners and suppliers. Boeing provides and maintains the interface, while the partners and suppliers provide the content. Figure 17 illustrated how the supplier portal could facilitate communication between the partners and suppliers.

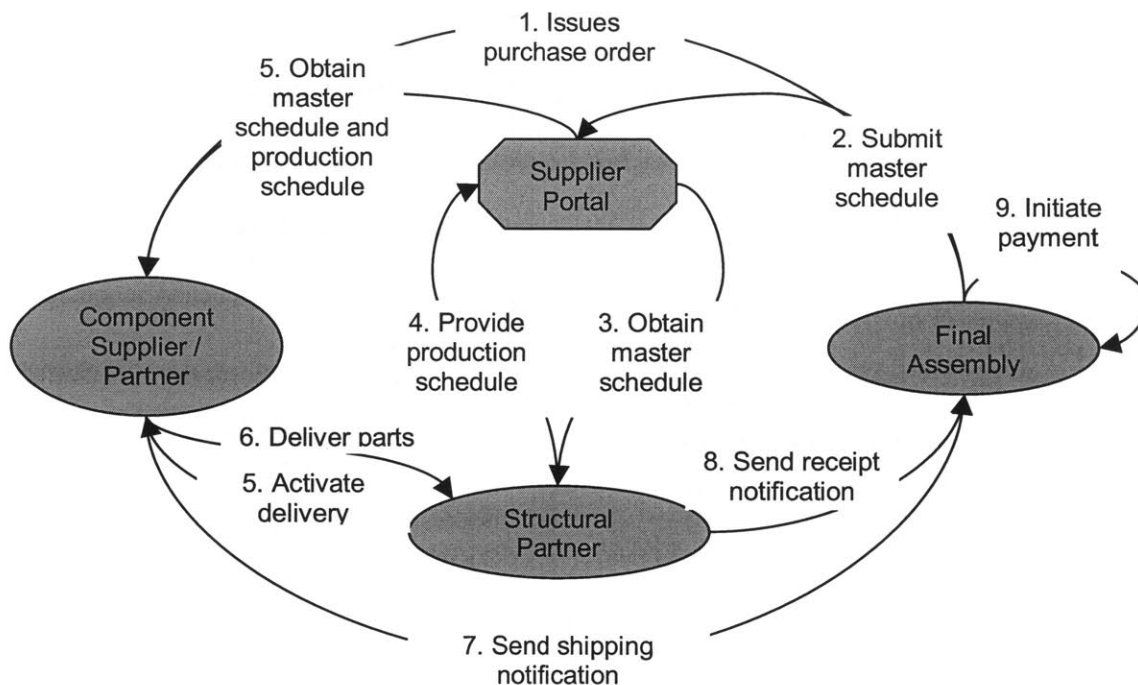


Figure 17 How a Supplier Portal Facilitate Communication between Boeing, Structural Partners and Component Suppliers

In the newly designed scheme, Boeing establishes a purchase order with individual partners and suppliers and submits master production schedule to the supplier portal. The master production schedule is the final assembly schedule. Structural partners

then obtain the master production schedule from the supplier portal and use it to draft their own production and component requirement schedule, which will also be submitted to the portal. Component suppliers can now go to the supplier portal and obtain the latest production and component requirement schedule from the structural partners, whom they need to supply to, and the master production schedule managed by Boeing. By integrating all these schedules, component suppliers can use the information to forecast their own production and inventory levels. When parts are needed, structural partners send out requests to activate delivery at the component suppliers. Upon delivery and receipt of components, component suppliers and structural partners will both send out notification to Boeing to initiate payment. Figure 18 outlines the roles and responsibilities using the supplier portal.

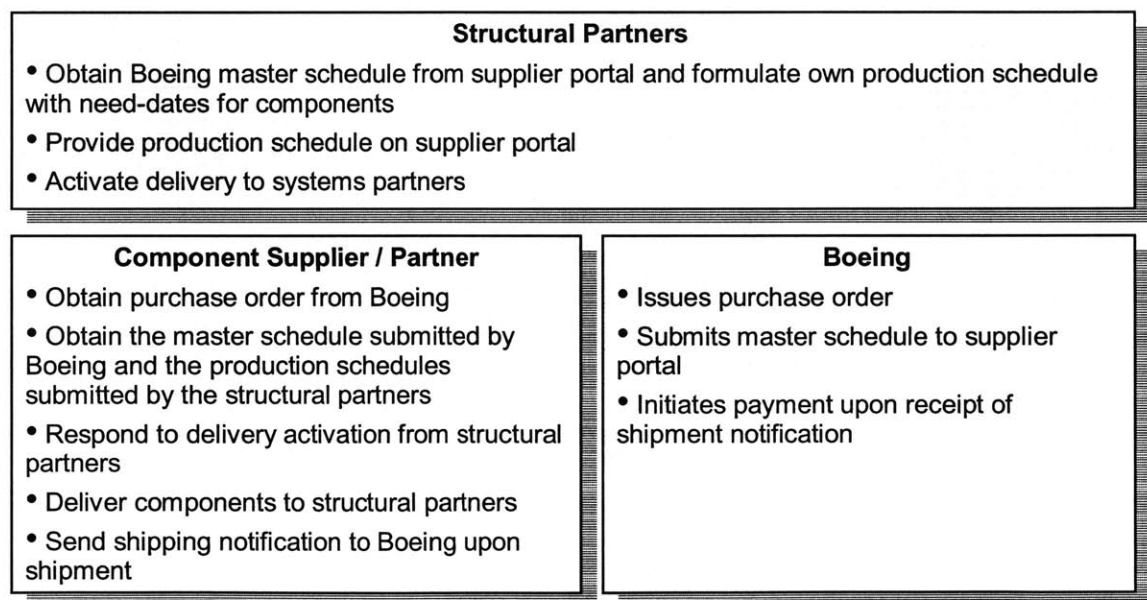


Figure 18 Roles and Responsibilities in Ordering and Scheduling

The newly designed scheme clearly defines the roles and responsibilities of Boeing, its partners and suppliers. It removes Boeing's participation from the day-to-day

ordering and scheduling activities, which should be performed by partners and suppliers since they are more intimately tied to the production and usage of the components. On the other hand, it offers Boeing the visibility into the entire supply chain, which allows the company to devise risk mitigation activities when things do not go as planned. For example, Boeing can obtain knowledge about a missing component early in the production process, and can decide whether there is a need to adjust the final assembly schedule accordingly.

In addition, this new design will streamline the overall ordering and scheduling process, eliminate mundane work from the supplier management department and allow the procurement agents to focus on other higher value-added activities, e.g. management and maintenance of the supplier portal to facilitate communication with the suppliers.

- **The Implementation**

- 1. Resource Requirements**

The redesign would be best led and coordinated by the supplier management department. Its execution requires a cross-functional project team with representatives from many different parts of the 787 program, as well as the partners and suppliers.

- 2. Risks**

Data integrity is the biggest risk of this redesign. Since partners and suppliers interact with the portal directly, Boeing cannot ensure the quality of data that are published on the portal. Therefore, issues with data integrity and their impact on production and component delivery will be pushed up the value chain and will eventually affect final assembly schedule and final product delivery. Since Boeing is responsible for the final product delivery, it is absorbing a large amount of the shock and cost from

having low data integrity on the supplier portal. Therefore, in order to mitigate such risks, Boeing needs to clearly communicate upfront to the partners and suppliers regarding the roles and responsibilities when using the supplier portal and align incentives with the suppliers accordingly.

3. Organizational Challenges

Setting up the technical solution for the supplier portal is relatively easy, yet encouraging the 787 program, both Boeing and its partners, to efficiently leverage the portal and integrate it into their day-to-day work is very difficult. First of all, all suppliers are very used to working with the supplier management department at Boeing to and from whom they provide and obtain their build and delivery schedules. Under the new system, the supplier would need to communicate with the supplier portal instead. There might be resistance coming from the suppliers since they will now be solely responsible for the integrity of the data, whereas in the past, there is more shared accountability with Boeing. Therefore, it is very important for Boeing to clearly define and communicate the expectations and accountability of data with the suppliers upfront.

C. Quality and Compliance

- **The Challenge**

Boeing currently has a compliance program which manages quality for drop-shipped components. Figure 19 highlights quality compliance management process.

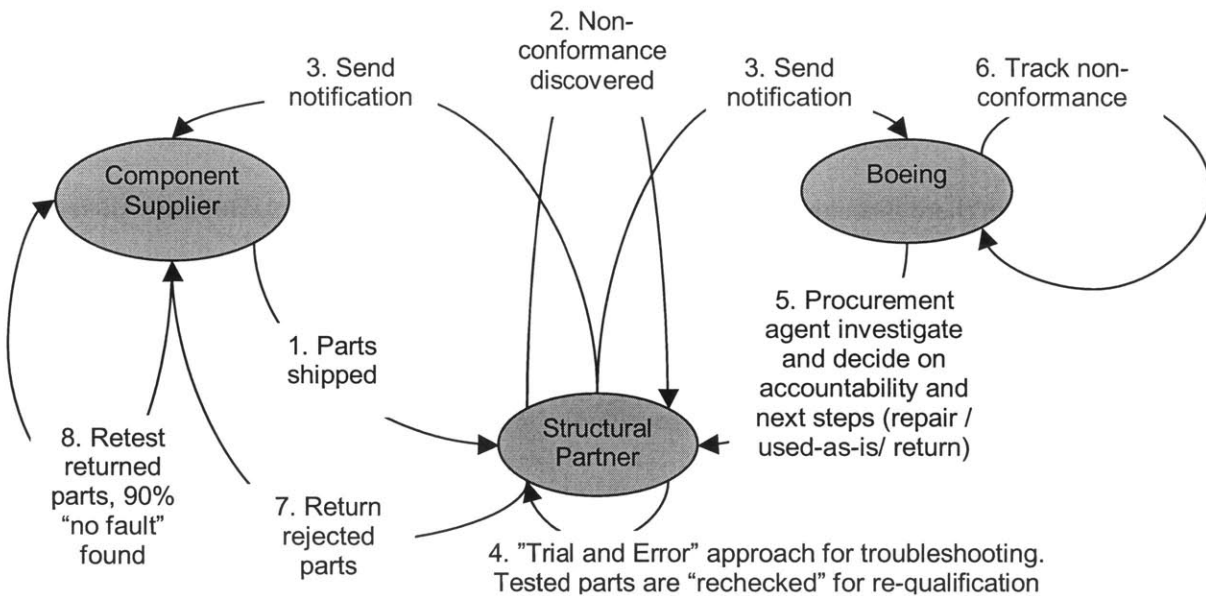


Figure 19 Quality Compliance Management Process

There are many different types of quality compliance issues. Some quality problems are discovered upon receipt in which case the structural partner will immediately send a notification to both the component supplier and Boeing. However, most of the issues are not discovered until the parts are actually being put in installation or into further work. When the systems do not function as they should after all the components are put together, troubleshooting is usually done. As per the regulations, all these parts have to be sent back to the suppliers for re-certification, despite that many of these pulled-out parts are perfectly functional. In fact, the component suppliers typically report "no fault found" in nearly all returned parts. In addition, since the structural partners do not own all these "pulled out parts," they have little incentive to return them for re-certification in a timely manner. Consequently, since Boeing owns these parts, the payment to suppliers is triggered once the parts leave the component supplier's dock in

the original shipment. Another consequence is that structural partners often need to order more than what the original production schedule requires in order to account for the “pulled out parts,” usually two to three times of the original order.

When there is a confusion regarding liability and accountability, Boeing will send out representatives to the suppliers and the partners to understand the cause of the non-conformance and decide on next steps (use, repair, discard), as well as track accountability and bill the suppliers accordingly. At times when accountability is unclear and difficult to trace, Boeing will become ultimately accountable since it owns the final product.

Like the ordering and scheduling process, the quality compliance management process is currently a model sufficient for the sustaining programs, but not for the 787 program when many of the components have to go through the drop-ship procedure.

- **Competitive Benchmarking**

Airbus has a very different culture in managing quality compliance from that of Boeing⁴⁶. They are much more hands-off with their suppliers since they have a history of enforcing the strict quality measurements listed on their contracts with the suppliers. In fact, their consortium structure enables such hand-offs management since the majority of knowledge and expertise resides at the suppliers. Therefore, their suppliers tend to be more independent and less reliant on directions from Airbus.

⁴⁶ Based on anecdotal data from conversations with industry experts.

- **The Recommendation**

One of the issues with the current quality management program is the difficulty and the long lag time in tracing accountability when there is a compliance issue. Currently, the program relies on Boeing's procurement agents traveling to the partner and supplier sites to locate the issues and report back to central procurement before deciding on next steps. This process is difficult to manage and requires a lot of resource support from the procurement group. Most importantly, there is a significant lag time (can be as high as three months) between the occurrence and the investigation of the non-conformance issue. If this process were to be implemented for the 787 program, Boeing would need to increase its resource support from its procurement department substantially since the majority of the components would be drop-shipped to non-Boeing facilities under the new program.

After studying the production and procurement systems at Toyota and Volkswagen⁴⁷, I discovered that both systems have one thing in common – that non-conformance is 100% managed at the drop-ship location (structural partners). For example, Toyota suppliers are required to be on site (at Toyota facilities or other partner facilities, depending on where installation takes place) to supervise installation, and the component is not considered “transferred to Toyota books” until the installation of the component has passed quality check. The supplier representative is also on site to answer questions and resolve compliance dispute. Therefore, all decisions can be made on the spot without going back and forth with procurement staff at the headquarters. Figure 20

⁴⁷ Data from Benchmarking Group, The Boeing Company.

illustrates how we could learn from this practice to modify the current non-conformance process for 787.

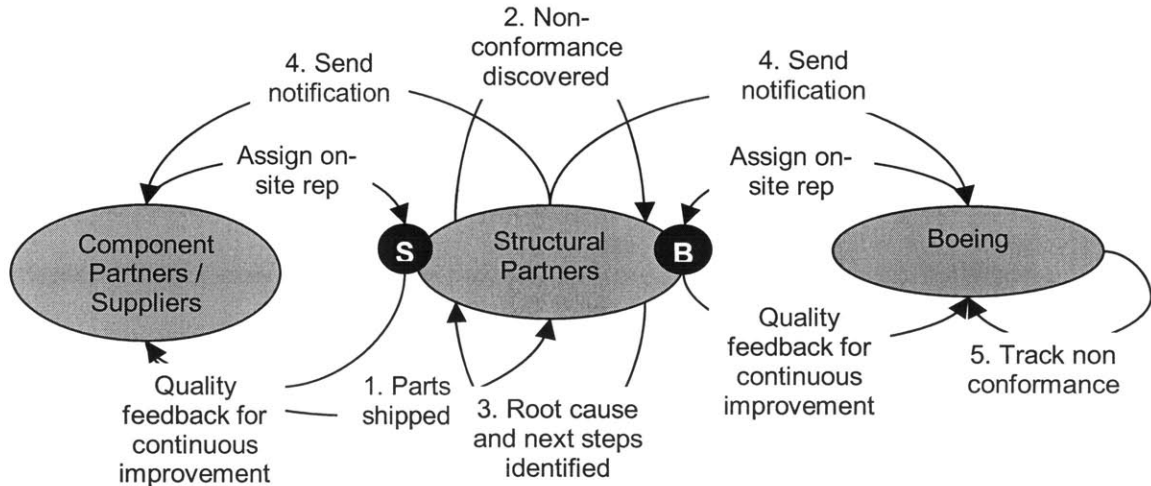


Figure 20 Applying Best Practice from Automotive Industry to Current Quality Compliance Management Process

Since most of the drop-shipped components will be installed at the structural partners' sites, it is important to have representatives from both the component suppliers and Boeing to be present there. These on-site representatives will be able to provide guidance for installation, identify the root cause of non-conformance, as well as resolve any dispute on the spot. They can also communicate quality issues back to their respective headquarters for continuous improvement. Since Boeing owns the component at installation, it is important for the Boeing on-site representative to have the authority to decide on the action (repair, replace or use-as-is) regarding the component in question. Currently, such decision authority resides in the procurement headquarters. Therefore, handling of any non-conformance issue requires communication with the headquarters, before any decision on the component can be made, resulting in significant lag time

between the occurrence and the resolution in the event of a dispute. On the contrary, under the new system, the Boeing on-site representative possesses authority to make such decision on the spot, enabling quick resolution of conflict as well as prompt action on the component in question.

While this redesign would incur additional cost, the benefits from reduction in non-conformance costs are substantial. Its impact can be calculated by the evaluating the cost of handling all the returned parts that are found to be no-fault, the cost of re-qualifying the parts, as well as the cost of capital for Boeing while these parts are in the compliance process.

- **The Implementation**

- 1. Resource Requirements**

While this new design would bring in substantial benefits, there are a lot of costs associated with it, namely the costs of placing company representatives at the suppliers' sites. While these representatives are very important in the early stage of the product lifecycle when the production processes have not yet stabilized, their roles diminish as the production processes mature. Therefore, they can be redeployed to other roles to reduce costs.

- 2. Risks**

The new process heavily relies on the company representatives in managing these supplier relationships. Since both technical knowledge and relationships reside with the on-site representatives, Boeing risks losing these valuable assets if there is turnover. Therefore, it might not be in Boeing's best interests to become dependent on its on-site

representatives in managing its supplier relationships. Such risks need to be taken into account when deciding on implementing the redesign.

D. Final Thoughts

Unlike the sustaining programs, the 787 program is designed to instill close collaboration between Boeing and its partners. If the 787 program succeeds, Boeing may consider applying this collaboration model to other airplane programs. Although the concept itself is sound and offers lots of tangible benefits, one may question whether the partnership model is appropriate for the company's conservative culture. Traditionally, employees are often encouraged to engage in activities to "make-sure" and "double-check." The many current systems and processes are designed to enable that. This culture means that when working with partners, Boeing people tend to get very closely involved with all suppliers on all processes. People consider it necessary to understand everything that goes into the airplane in order to make sure nothing goes wrong, because Boeing is ultimately accountable for the final product. Indeed, many argue that such conservatism is appropriate for an aircraft manufacturer, as the quality of the product must be ensured at all cost."⁴⁸

The new supply chain model relies heavily on trust between Boeing and the partners. If Boeing ends up managing the suppliers' business, it will not be able to reap the benefits from the collaboration. On the other hand, instead of being the passive players they were in the past, partners also need to take a more active role in managing this collaboration. Indeed, both Boeing and the partners will need to move out of their

⁴⁸ Anselmo, Joseph. "Supply Chain Reforms Too Late for Many Manufacturers,". Aviation Week and Space Technology, Nov 14,2004.

current paradigms. As I reflect on this issue, I recall that Professor Jonathan Byrnes once said in his class – Case Studies in Supply Chain Management, “The hard part is the easiest part; the soft part is the hardest part.” What I found is that developing the recommendations is not complicated, but enabling the organization to achieve them is what is truly daunting.

IV. Concluding Remarks

The 787 program offers an exciting opportunity for the Boeing Company. Not only does it represent a new market opportunity, but it also provides a platform on which the company can implement many new business processes, including a new partnership and supply chain structure. This new collaboration model, if executed successfully, could conceivably turn the company around and the 787 program could become a pilot program for other sustaining airplane programs.

However, as discussed in this thesis, implementing new supply chain processes is not without challenges. Many of these challenges are tactical, and can be resolved by better technologies and coordination. Yet, enabling them across the organization requires much more than tactical solutions. It requires a fundamental change in thinking on the way how business is conducted and a paradigm shift in the definition of relationships between Boeing and its partners. More importantly, such changes cannot only happen at the senior management level, but rather, at all levels in the organization. It is of paramount importance for Boeing employees at all levels to recognize this need for a paradigm shift, in order to drive the 787 program home.

“Paradigmatic change is very important in business. It has the potential to create major new value and to renew a company, but its is very difficult to accomplish in the absence of a business crisis” – Jonathan Byrnes⁴⁹

⁴⁹ “The Challenges of Paradigmatic Change,” Jonathan Byrnes. Harvard Business Review – Working Knowledge, Oct 4,2004.

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